Geologic Resource Evaluation Scoping Summary
Tuzigoot National Monument, Arizona

Geologic Resources Division
National Park Service
U.S. Department of the Interior

The goal of the Geologic Resource Evaluation (GRE) Program is to provide each "natural area" park with a digital geologic map and accompanying geologic resource evaluation report. As a means of obtaining this goal, the NPS Geologic Resources Division (GRD), which administers the inventory, coordinates scoping meetings that bring together park staff and local geologic experts. The scoping process includes an evaluation of the adequacy of existing geologic maps and a discussion of park-specific geologic management issues. When possible, a site visit with local experts is also part of the scoping process. Outcomes are a scoping summary (this report), and ultimately a digital geologic map and geologic resource evaluation report. Along with the completed digital map, this scoping summary will serve as the starting point for compiling the final GRE report for Tuzigoot National Monument.

The National Park Service held a GRE scoping meeting at Dead Horse State Park near Cottonwood, Arizona, for Tuzigoot National Monument on Wednesday, May 10, 2006. After the meeting, John Schroeder (archaeologist for Montezuma Castle and Tuzigoot national monuments) led a field trip to view the alcoves at Montezuma Castle National Monument and the ruins at Tuzigoot National Monument.

Table 1. Scoping Session Participants

Name	Affiliation	Phone	E-Mail
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Melanie Ransmeier	NPS Geologic Resources Division (/GIS specialist)	303-969-2315	melanie_ransmeier@nps.gov
John Schroeder	Montezuma Castle and Tuzigoot national monuments (archaeologist)	928-649-6195	john_schroeder@nps.gov
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Laurie Wirt	U.S. Geological Survey (geologist)	303-236-2492	lwirt@usgs.gov

Discussion during the meeting addressed geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues related to these features and processes, and potential monitoring and research needs. Melanie Ransmeier (NPS Geologic Resources Division) facilitated the discussion of map coverage, and Lisa Norby (NPS Geologic Resources Division) led the discussion of geologic processes and features. Participants at the meeting included NPS staff from Tuzigoot and Montezuma Castle national monuments, the Geologic Resources Division, Sonoran Desert Network, and

Southern Arizona Office, as well as cooperators from the U.S. Geological Survey (USGS), Arizona Geological Survey, Northern Arizona University, and Colorado State University (table 1).

Status of Scoping and Products

As of May 2006, the NPS Geologic Resources Division had completed the scoping process for 169 of 270 "natural resource" parks. Staff and partners of the GRE Program have completed digital maps for 69 parks. These compiled geologic maps are available for download from the NR-GIS Metadata and Data Store at http://science.nature.nps.gov/nrdata. The U.S. Geological Survey, various state geological surveys, and investigators at academic institutions are in the process of preparing mapping products for 49 additional parks. Writers have completed 22 GRE reports with 60 additional reports in progress.

Park and Geologic Setting

Tuzigoot is an ancient village or pueblo inhabited by the Sinagua culture from approximately AD 1000 to 1450. The pueblo consisted of approximately 110 rooms including two- and possibly three-story structures. The Sinagua were agriculturalists with trade connections that spanned hundreds of miles. In order to protect these ruins and surrounding areas, the site was declared a national monument on July 25, 1939, with changes to the boundaries in 1978 and 2006. On March 28, 2006, the National Park Service acquired the 324-acre Tavasci Marsh from Phelps Dodge through a land trade. Addition of the marsh physically preserves the full story of the daily lives of the Sinagua people: They used water from the marsh and river to irrigate fields. They used riparian plants for weaving and making utensils, and wildlife and riparian plants were sources of food.

Table 2. Geologic Settings of the Verde Valley

Period	Events	Representative Rocks	Setting
Neogene (25 Ma–present)	Canyon cutting and valley erosion Basin sedimentation Faulting Volcanism	Rim basalts Verde Formation Hickey basalts	Modern landscape Swamp and shallow lake Volcanoes
Paleogene (35–65 Ma)	Regional mountain building and plateau uplift Tectonic forces produce folding and faulting (e.g., monoclines) Sediment shed from uplifted areas	Local conglomerate above Mogollon Rim	Phoenix is an alpine city. Cottonwood River is at 10,000 feet in elevation.
Mesozoic (65–250 Ma)	Deposition of marine and continental sediments Erosion	Not well represented in Verde Valley; some rocks in Sycamore Canyon (e.g., Moenkopi and Chinle)	
Paleozoic (250–525 Ma)	Marine and continental sedimentation Eolian deposits Numerous periods of erosion produce unconformities	Flat-lying sedimentary rocks in canyon walls (e.g., Tapeats sandstone; Martin [fossiliferous], Moenkopi, and Chinle Formations; Supai Group)	Arid river valley Inland sea
Long period of erosion			
Proterozoic (>1.6 Ga)	Sedimentation Volcanism Mountain building	Crystalline basement (i.e., schist and related metamorphic rocks) Yavapai Supergroup Prescott Granite	Island arcs

Tuzigoot National Monument is situated along a ridge on the eroded Verde Formation. The ancestral and present-day Verde River created the floodplain and deposited the terraces upon which the ruins are situated. Tavasci Marsh—one of the largest marshes in Arizona—and Peck's Lake are the remains of an abandoned meander of the Verde River. Tavasci Marsh is on the outside of the meander and Peck's Lake is a cutoff "oxbow" lake. The Audubon Society of Northern Arizona has designated Tavasci Marsh as an Important Bird Area.

Part of the Central Highlands of Arizona, Tuzigoot National Monument is located in the Verde Valley. The Central Highlands is a transition zone between two physiographic provinces: the Basin and Range to the south and west and the Colorado Plateau to the north and east. Tilted fault blocks that form long, asymmetrical ranges or mountains and broad, intervening basins characterize the Basin and Range. The Colorado Plateau is a high, relatively undeformed area. A distinctive feature of the Central Highlands is the Mogollon Rim, which extends more than 200 miles from the White Mountains in eastern Arizona to the headwaters of the Verde River on the western side of the state. Elevation exceeds 7,000 feet along the Mogollon Rim, just 20 miles north of the monument.

The major geologic components of the Verde Valley are the (1) basin sediments; (2) lacustrine, swamp, and playa deposits of the Verde Formation; and (3) uplifted Paleozoic sedimentary rocks. The ancestral and present-day Verde River deposited the basin sediments, which consist primarily of semi-consolidated alluvium and igneous rocks such as dikes and basalts. Also included in this category are the Quaternary river sediments, which form a rather shallow veneer in only part of the basin. The uplifted Paleozoic sedimentary rocks occur along the margins of the valley and are exposed along the Mogollon Rim (table 2). Included in this third category is the Paleozoic Supai Group, which is the regional aquifer to the east and northeast of the monument. Rocks of the Supai Group are underlain by the Redwall limestone, which is known to have caves and rubble zones. Overlying these rocks are the Verde Formation (7–9 million years old) and basalts, such as the 15-million-year-old Hickey basalt and the 5-million-year-old Rim basalt. The Verde Formation is a freshwater limestone that contains some halite, clay beds, and volcanic ash that is interbedded with the basalt flows. It was deposited in an environment consisting alternately of a large swamp, shallow lake, and playa. Lava flows and tectonic activity periodically obstructed this swamp-lake-playa system, shifting from an open to closed basin.

By about 2 million years ago, the Verde Valley was filled with sediment. The ancestral Verde River initially flowed over the limestone and then began to erode it. Hence, rivers began to drive landscape evolution, ultimately forming the present landscape. Large floods occurred in 1891, 1906, 1920, 1938, 1978, 1980, 1993, and 1995, all of which helped to incise the river. Moreover, the 1993 flood had a strong impact on the current channel form (P. Pearthree, Arizona Geological Survey, written communication, June 7, 2006). In addition to eroding the Verde Formation via downcutting, the Verde River and its tributaries produced terraces, meanders, and the present floodplain. Alluvial fans were deposited along the edges of the valley. A series of three groups of alluvial fans are evidence of past landscapes within the Verde Valley, with the highest fans preserving the most ancient landscapes.

Geologic Maps for Tuzigoot National Monument

During the scoping session on May 10, 2006, Melanie Ransmeier (NPS Geologic Resources Division) showed some of the main features of the digital geologic map model used by the GRE Program—the NPS GRE Geology-GIS Geodatabase Data Model. This model reproduces all aspects of a paper map, including notes, legend, and cross sections, with the added benefit of being GIS compatible. Staff members digitize maps or convert digital data using ESRI ArcMap software. Digital data are provided in each of the following three formats: geodatabase, shapefile, and coverage. Layer files (legends), FGDC-compliant metadata, and a Windows HelpFile that captures ancillary map data, are also part of the final dataset.

Parks in Inventory and Monitoring Networks have identified 7.5-minute "quadrangles of interest." In general, digital geologic data from 7.5-minute quadrangles (scale 1:24,000) suit the purpose of geologic resource evaluations. The geologic features mapped at this scale are equivalent to the width of a one-lane road. Quadrangles of interest are used as a starting point for discussion in determining what the final digital geologic map for a park will include. A recent policy change for the GRE Program, however, excludes from potential digitizing any quadrangles that do not include a portion of the park. This summary attempts to outline an action plan that incorporates this new policy while providing a digital map useful for resource management.

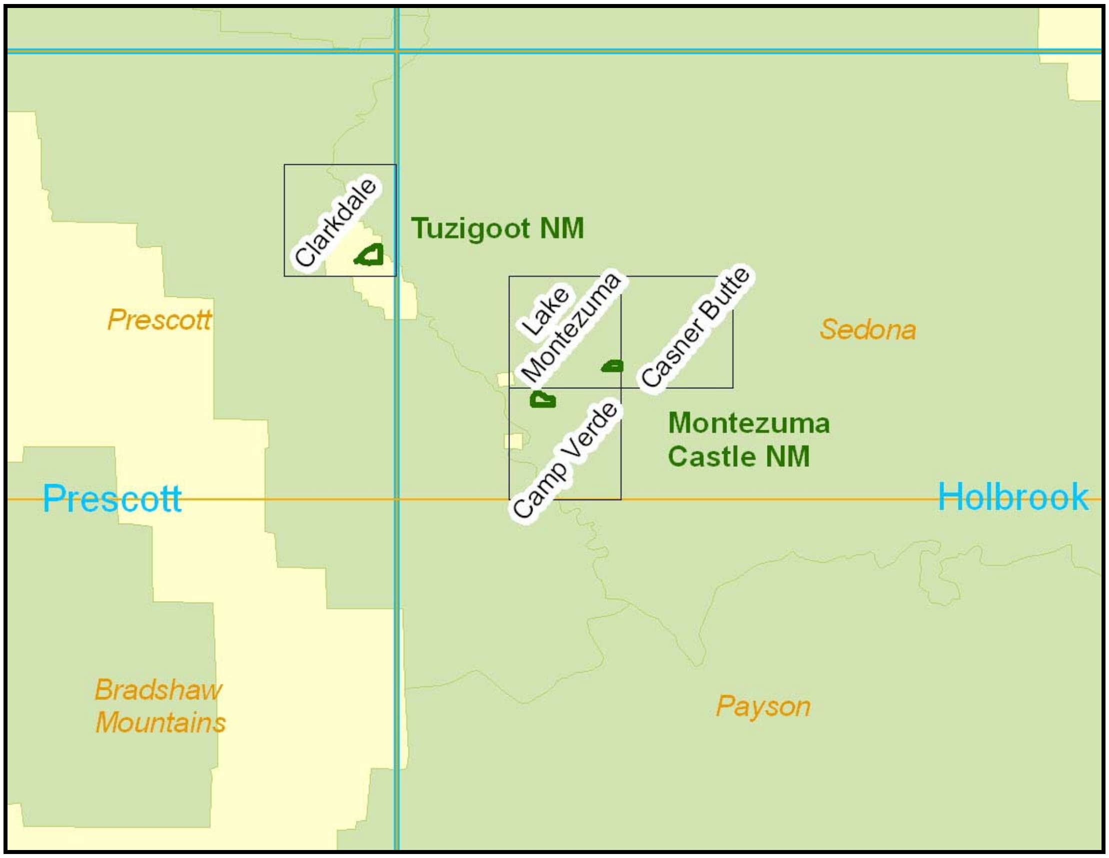

Figure 1. Quadrangles of Interest for Tuzigoot National Monument, Arizona. The 7.5-minute quadrangles (scale 1:24,000) are labeled in black; names in yellow indicate 30-minute by 60-minute quadrangles (scale 1:100,000). Names in blue indicate 1-degree by 2-degree sheets (scale 1:250,000). Green outline indicates the boundary of the monument.

Tuzigoot National Monument has one 7.5' quadrangle of interest, Clarkdale, which is situated on the Prescott 30' × 60' sheet (see fig. 1 and table 3). The map by House and Pearthree (GMAP 1091) provides surficial geology for the Clarkdale quadrangle. The Lehner (1958) map of the Clarkdale 15' quadrangle (GMAP 1092) provides the best available bedrock geology for the area. When the unpublished "Dewitt map" of the Prescott National Forest and vicinity (GMAP 5615) is finalized, it will provide the most up-to-date geologic compilation for this quadrangle. As of June 2006, the U.S. Geological Survey had completed technical reviews of this map. The map currently resides with the Central Region Publications Group, and USGS management is attempting to expedite its publication (L. Wirt, USGS–Denver, written communication, June 23, 2006).

Table 3. GRE Mapping Plan for Tuzigoot National Monument

Quadrangle	GMAP[1]	Citation	Scale	Format	GRE Initial Assessment	GRE Action
Clarkdale	1091	House, P.K., and Pearthree, P.A., 1993, Surficial geology of the northern Verde Valley, Yavapai County, Arizona—Clarkdale 7.5' quadrangle [sheet 1 of 4]: Arizona Geological Survey Open-File Report OFR 93-16; scale 1:24,000.	1:24,000	Paper	This map provides surficial geology for nearly all of the Clarkdale quadrangle and all of Tuzigoot National Monument.	Digitize this map to provide surficial geology.
Clarkdale	1092	Lehner, R.E., 1958, Geology of the Clarkdale quadrangle, Arizona: U.S. Geological Survey Bulletin 1021-N [Parts A–N bound in one volume—Contributions to general geology], scale 1:48,000.	1:48,000	Paper	This map provides bedrock geology for the entire Clarkdale quadrangle and is good quality. It provides the best bedrock geology currently available.	Digitize the Clarkdale 7.5' section of this 15' map to provide bedrock geology.
Clarkdale	5615	DeWitt, E., Langenheim, V.E., Force, E., Vance, K., and Lindberg, P.A., *with* a digital database by Hirschberg, D., Pinhassi, G., and Shock, N., 2006, Geologic map of the Prescott National Forest and headwaters of the Verde River, Yavapai and Coconino counties, Arizona [in press]: U.S. Geological Survey Miscellaneous Investigations Map I-[unpublished number], scale 1:100,000, 2 sheets.	1:100,000	Unpublished	Although recommended for use by USGS and NAU participants, this map is currently unpublished and unavailable for the Tuzigoot area of interest.	None *Note:* When published, this map will provide the most current bedrock data for the area.

[1]GMAP numbers are identification codes used in the GRE database.

Geologic Features, Processes, and Issues at Tuzigoot National Monument

The scoping session for Tuzigoot National Monument provided the opportunity to capture a list of geologic features and processes, which will be further explained in the final GRE report. During the meeting, park staff identified two priorities related to these features and processes:

1. Disturbed lands (i.e., mining impacts such as visual impairments, altered hydrology, and degraded water quality)
2. Fluvial features and processes (i.e., altered hydrology of Peck's Lake–Tavasci Marsh system)

Disturbed Lands

In addition to changes in the hydrologic regime of the Peck's Lake–Tavasci Marsh system (see "Fluvial and Lacustrine Features and Processes"), historic copper mining in the nearby town of Jerome resulted in acid mine drainage and tailings piles from the smelter in Clarkdale, which filled part of the oxbow on the Verde River upstream from the monument. The practice of dumping tailings on the floodplain ended in the 1940s. However, recent mining practices included spreading slurry just outside the entrance to Tuzigoot. Phelps Dodge is currently in the process of burying these tailings. After burial, the company will no longer "manage" them, hoping that native vegetation will populate the area (J. Schroeder, Montezuma Castle and Tuzigoot national monuments, written communication, June 23, 2006).

Portions of the marsh were drained for agricultural fields in the past. Moreover, according to the Tucson Audubon Society, grazing has occurred on the Phelps Dodge land for more than 50 years and has significantly impacted the riparian habitat (http://www.tucsonaudubon.org/azibaprogram/ibacons.htm). Participants noted that exotic Bermuda grass was planted in the marsh to feed cattle.

Fluvial and Lacustrine Features and Processes

The present-day Verde River is an active system with dynamic channel morphology, which is a potential threat to the road into the monument. The river is known to overflow its banks during floods. Historic copper mining in Jerome has adversely affected the water quality in Verde River. According to the monument's Web site, "High levels of sodium, turbidity, boron, mercury, sulfate, copper, zinc, manganese, iron, ammonium, and selenium are often recorded" (http://www.nps.gov/tuzi/pphtml/subnaturalfeatures20.html). In addition, participants at the meeting mentioned the presence of arsenic.

The boundary of Tuzigoot National Monument recently expanded to include Tavasci Marsh—Arizona's largest freshwater marsh. Once the primary route of the Verde River, Tavasci Marsh was isolated about 10,000 years ago when natural climatic conditions altered the rivers course, cutting off the oxbow. Today that oxbow contains Peck's Lake, Tavasci Marsh, and mesquite woodland. Tavasci Marsh hosts a broad array of Arizona's wildlife: river otters, beaver, southern bald eagle, peregrine falcon, rails, and ducks.

Historically both Tavasci Marsh and Peck's Lake were maintained by a series of numerous small springs, mostly emanating from the north side. The most obvious of these is Shea Spring, easily recognized by the adjacent towering cottonwoods that usually leaf out a few weeks ahead of the other trees in the area. Peck's Lake is now an artificial impoundment and water is supplied via a tunnel from the dam to the lake. In the present system, water from the Verde River flows into and through Peck's Lake then into the marsh. The Tavasci Marsh serves as a "filtering system" for Phelps Dodge copper-mining waste products (tailings). Participants at the scoping meeting noted that the slurry from mining that flows through Peck's Lake and into Tavasci Marsh degrades water quality. Restoration of the marsh's hydrology will require identifying the natural outlet and restoring the artificially constructed hydrology of the lake-marsh system to its natural conditions.

The Phelps Dodge land just outside the entrance to the monument was the site of a planned 900-home, golf-course development, which will radically alter the calm, rural setting and viewshed. Mine tailings fill this area to a depth of approximately 60 feet. These tailings are being spread out and covered with soil as part of the restoration of the site. Various groups are working toward conservation of the area (e.g., Tucson Audubon Society and the Northern Arizona Audubon Society). As of June 2006, Phelps Dodge had tabled the idea for developing this area. However, park staff thinks it is likely that Phelps Dodge will reconsider the idea once the land reclamation project is completed (J. Schroeder, Montezuma Castle and Tuzigoot national monuments, e-mail communication, June 2, 2006).

Caves and Karst Features and Processes

On March 28, 2006, the National Park Service acquired the 324-acre Tavasci Marsh from Phelps Dodge through a land trade. The newly acquired land has the potential for caves and karst features, though an inventory has not been conducted.

Hillslope Features and Processes

The main hill at the monument has differential fill on its eastern and western slopes. The eastern slope is sliding, creating a crack that runs from the top of the pueblo down the southern slope. Park staff is monitoring this movement with crack gauges.

Small landslides associated with rain events occur on the northeastern boundary of the monument. In the future, park managers may construct a trail in this area, so a geohazards "risk assessment" may be useful during planning and design of the trail.

Geothermal Features and Processes

Verde Hot Springs is located about 50 miles southeast of Tuzigoot, near Childs, Arizona. It is the site of a former resort, which has not had paying customers since the 1930s. A concrete foundation, which encircles a number of pools, remains. According to various Web sites (i.e., http://www.fossilcreekaz.com/pages/verde.html and http://www.reith.ca/verde/), the hot springs is between 95°F and 104°F. In 1980 the U.S. Geological Survey published a map showing the areas with geothermal resource s in the Verde Valley, which would undoubtedly be a good reference for park managers (Ross and Farrar, 1980).

Water emanating from Shea Spring into Tavasci Marsh has elevated temperatures; the Northern Arizona Audubon Society documents 68°F water (http://nazas.org/NAASConservation.htm#TaMa), which supports the theory of a geothermal source. Groundwater feeding this spring flows through the Verde Formation year-round. According to Laurie Wirt (USGS–Denver), many springs along the Verde River emerge from large faults or karst. These springs have the same water temperature as Tavasci Marsh. The largest spring known to Wirt is at Page Springs, which is 6 miles east of Tavasci Marsh. At this location, fisheries are operated because the warm water encourages rapid fish growth. This temperature is fairly common for some of the other carbonate springs along the Verde River. Bubbling, Lolomai, and Turtle springs are other springs upstream from Page Springs that are tributary to Oak Creek. Like Montezuma Well, the springs in the Verde Valley typically emerge through the Verde Formation, but probably come through the Paleozoic section below. The springs along Oak Creek also emerge just downgradient from a large mass of volcanic rocks, where there appears to be a fault. Hence, the geothermal system is rather complicated (L. Wirt, USGS-Denver, written communication, June 23, 2006).

Paleontological Resources

Invertebrates (e.g., brachiopods, corals, mollusks, stromatolites, and conodonts) are locally abundant at Tuzigoot National Monument. Although the National Park Service has not completed an inventory of the paleontological resources in the monument, past investigations (e.g., Beus, 1978) are indicative of potential finds. As in Montezuma Castle National Monument, the Verde Formation exposed in Tuzigoot may yield Pliocene animal tracks or other fossils (J. Kenworthy, National Park Service, written communication, April 13, 2006).

Seismic Features and Processes

No active faults are known to occur at Tuzigoot National Monument. Hence, the monument has low to moderate seismic potential. The closest fault is the Camp Verde fault zone, which runs along the base of the Black Hills. The active portion of the fault is 10–15 miles east of the monument. Other active faults in the area include the Big Chino fault northwest of the Verde Valley, the Cottonwood Basin fault in southeastern Verde Valley, and the Lake Mary fault southeast of Flagstaff, Arizona. The Flagstaff area has an earthquake potential of between 6.0 and 6.9 in magnitude, which would be felt at the monument. Historic earthquakes in the Verde Valley are documented as intensity VII (on the modified Mercalli scale), during which chimneys fell.

Unique Geologic Features

Unique geologic features may include features mentioned in a park's legislation, features of widespread geologic importance, geologic resources of interest to visitors, or geologic features worthy of interpretation. Also, type localities and age dates are considered unique geologic features. Unique geologic features at Tuzigoot National Monument include biological soil crusts. Students of Jayne Belnap (U.S. Geological

Survey) have completed field work on this subject at the monument. Because of the limestone, however, biological soil crusts are not widespread here.

References

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